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STEPS
TO THE MATHEMATICS.

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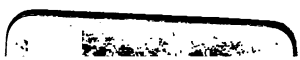

THE

MECHANIC'S AND SCHOOLBOY'S

STEPS TO THE MATHEMATICS,

BEING

THE SCIENCE OF GEOMETRY

ARRANGED ON A NOVEL PRINCIPLE,

AND EXPLAINED IN THE MOST FAMILIAR MANNER, SO THAT IT CAN BE

EASILY COMPREHENDED BY

PERSONS STUDYING WITHOUT THE HELP OF A MASTER;

AND WILL BE FOUND EQUALLY USEFUL TO THE TEACHER,

IN INSTRUCTING HIS PUPILS.

BY

JOHN QUESTED,

AUTHOR OF THE "ART OF LAND SURVEYING," "A TREATISE ON RAILWAY SURVEYING AND LEVELLING."

LONDON:
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PREFACE.

WHEN we reflect on the multitude of works extant on this subject, it may appear both presumptuous and unnecessary, that the Public should be encumbered with another, and that other laying claim to no pretensions of new and important facts, setting no disputed point at rest;—in short, not introducing a Problem which may not be met with in other works. Still the compiler* trusts that it may receive encouragement. He has endeavoured to write it in a clear, and unostentatious style, that it may be easily understood by the student, without having recourse to a master; and the arrangement, he hopes, is such, as to give the pupil every facility.

* I prefer the word *Compiler*, for it certainly would be arrogating to myself a credit ill deserved, to say *Author*, inasmuch as, following the beaten track of my Predecessors, I cannot fail using both their words and definitions; and, let who will write on this subject, he becomes, *Nolens volens*, a Plagiarist. Much of the idea of the arrangement is derived from an old work which fell into my hands some time ago; and he, from whom I have plucked a feather, took his plumage from a French Bibed of the genus Euclid.

It has been frequently remarked by young students, that the instructions how to work a problem, are often confused; and much of the confusion arises from the letters of reference, A, B, C, &c., following consecutively, in the line of type; careless pupils, therefore, not paying attention to the punctuation of the rules, confound themselves. This, the compiler has endeavoured to correct, by *giving to each distinct operation and reference to the diagram, a separate line; and by placing the letter or letters referring to the diagram, on the right hand,* so that they may attract the eye immediately. On the left hand margin, are placed figures relating to pages, in other parts of the work, containing some remarks on the subject treated of;—for example, on Page 16 opposite the words "Bisect the line, C *d*," stand the figures 18, and the student by turning to page 18 will find instructions how to bisect a line.

Those who have, like the writer, been employed in the instruction of youth, have doubtless, frequently remarked the difficulty which boys experience in retaining the technical words and phrases. Unless they have some knowledge of Greek and Latin, (from which languages the greater part of these words are derived) they can trace no affinity, and consequently can see no reason, for certain geometrical figures, having such apparently odd names. The Greek language, being in itself so comprehensive, one word often expressing what would require several to convey the same meaning in English, Geometricians

have retained the original words, or have rather *Anglicised* them.

Imagining that some facility may be afforded to the learner, the compiler has appended a Glossary, in which the derivation and meaning of many of these words may be found; and by which the pupil may see, that strange as they may sound to his ear, the signification, nay, the very description of the figure or operation, is in the original word fully explained.*

Some of the remarks may appear simple and unnecessary, to those who have previously studied this science; but, on reflection, even they, may perhaps remember, that, while studying, with the fear of the ferule before their eyes, they have been sorely puzzled by what may now be clear and easy of comprehension to them. It should also be borne in mind, that this little work is not written for the proficient; but as a means, for the beginner, to arrive at proficiency by preparing his mind for more erudite and elaborate works. There is one class of people in particular, to whom the writer cherishes the idea that his efforts

* The writer begs to tender his acknowledgements to his friends for their assistance in the Glossary, without whose valuable aid he could not have compiled it.

Such is the *march of intellect*, and such the rage for display, that the writer is often amused by reading advertisements of new inventions, in which patentees delight at once to puzzle and astonish the public. In the "Times," of this day, after several advertisements headed "Panklibanon," in which are introduced the classic name of "Purdonium," for a *coal scoop*, the patent Thermio stove &c., follows one, commencing with the astounding word Anhydrohepseterion, or a *Machine to cook potatoes*. If our language be so destitute of words, as not to afford one for a mere cooking apparatus, surely we cannot wonder at Geometricians retaining the original words, of a science, which owed its birth to the men who spoke the Language, in which the definitions are handed down to us.

may be of service. He alludes to the Mechanics, that class who were formerly of opinion, that

> "Where Ignorance is bliss,
> 'Tis folly to be wise."

but among whom, there is now engendered a desire to improve their mental faculties, and by that moral force, elevate themselves from the most degrading slavery,—the slavery of ignorance, the nearest approximation to the brute creation. While this laudable emulation is daily extending, while the Mechanic, who toils with the implements of his handicraft, is searching into the more hidden mysteries of his calling,—himself, asking the "Why," and seeking the "Because" of certain results; while he is in truth, enjoying the real "feast of reason;"—while he attends the Institutions which he himself contributes to support, for the purpose of self-instruction,—we may hope, with confidence, to find that improvement in his moral and social station, which truly makes a nation great. And it is to that useful, and now intelligent class, these pages may be found adapted.

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GEOMETRY.

79 Geometry (derived from two Greek words γη the earth, and μετρον a measure) is of very ancient date, and perhaps Hermès Trismegistus, who lived in the time of Moses, was the first who reduced it to a system. It passed through several gradations of improvement, until the great Euclid, by his erudite works, so perfected this grand science, that upon his principles, are based all the modern works.

It is generally considered to owe its origin, like most of the Arts and Sciences, to the wants and necessities of mankind; for, after the curse pronounced upon the first fratricide, that he should be a "Tiller of the Earth," and after men began to multiply, so that a division of land, became necessary, recourse was had in its rude state to Geometry. The periodical overflowings of the Nile, obliterating the divisions and boundaries; and the rich sediment left by that far-famed river, in its onward course to the Mediterranean, being considered valuable for the cultivation of the soil, in the immediate neighbourhood, the ingenuity of man was taxed to devise means of restoring the lost boundaries, and of apportioning the rich manure.

Thus, like Rome, "from small beginnings," has arisen a science, on which are based all the sublime calculations of Astronomy,—all that art which teaches man to traverse the trackless ocean, with precision, nearly amounting to certainty, as to the time and route of his destination. The Architect, in rearing his stupendous piles, lays his foundation, elevates his walls, and adds the crowning dome, or pointed spire, by the aid of Geometry. To this science also are we indebted for the construction of those roads, which, by the application of steam, seem to annihilate time and space.

Geometry is considered as divided into Practical and Speculative; it is of the former, the following pages treat; and the writer earnestly hopes, that his humble exertions to assist the Teacher in imparting, and the Pupil in receiving instruction, may meet with success.

DEFINITIONS.

Reference Page.

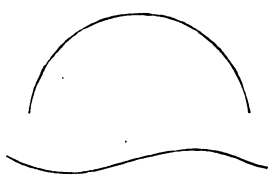
A POINT has neither length, breadth, nor thickness.

74 A LINE has length, but neither breadth nor thickness.

Lines are either right, curved, or mixed.

By a *right line* is understood that which is commonly called a *straight line*, and is drawn from point to point in the most direct way as A B,

73 A *curved line* does not run direct from point to point, but continually changes its direction.



A line is said to be mixed when it is partly *curved* and partly *right.*

In the solutions to problems and in practical work, when the word line is mentioned, unless qualified by the terms *curved* or *mixed*, it is understood to be a *right line.*

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74 The right line is again distinguished as being hori-
77.75 zontal, vertical or oblique.

In geometrical definitions, as in common parlance, a horizontal line, implies one that is level, or running parallel with the lower edge of the paper.

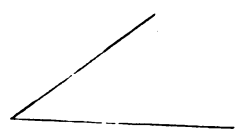
The vertical line is perpendicular to the horizontal.

An oblique line is a straight line, neither in a horizontal nor a vertical direction.

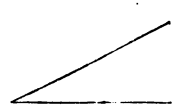
HORIZONTAL. VERTICAL. OBLIQUE.

3 Parallel lines are such, as maintain a constant distance from each other, and therefore would never meet. Parallel lines may be both right and curved.

A plane angle is the inclination of two straight lines
76 to one another in a *plane*, which meet together, but are not in the same direction.



76 A plane rectilineal angle is the opening of two lines,
77 meeting at a point, which point is called the Vertex.



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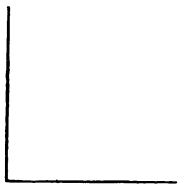
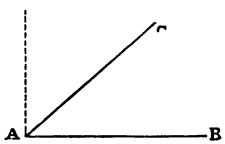
73 An angle is either right, acute, or obtuse.
A right angle is formed by one line standing in an upright or perpendicular direction to another line,

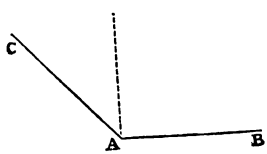


and thus forms an angle of 90°, for as the proper-
9 ties of angles are based on circles, and every circle contains 360°, it is evident that if a line be drawn from the rim of the circle through the centre to the opposite rim, such line divides the circle into two halves of 180° each, and a perpendicular line raised from the centre to the circumference will form a Quadrant or quarter of the circle, equal to 90°.

73 An acute angle is less than a right angle, and therefore cannot contain 90°, as C A B.



75 An obtuse angle is greater than a right angle, and therefore contains more than 90°, as C A B.



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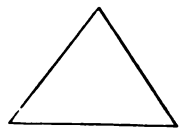
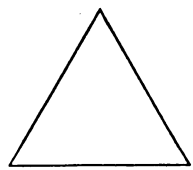
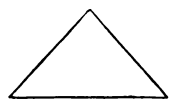
77 A triangle is a figure of three sides, being the smallest number of right lines which can include a space.



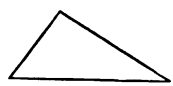
74 An equilateral triangle is one having all its sides equal.



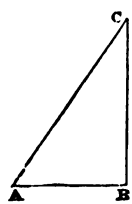
74 An isosceles triangle has two of its sides equal.



76 A scalene triangle has its sides all unequal.



5 A right angled triangle has one of its angles right, or containing 90°.



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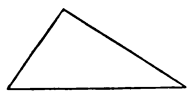
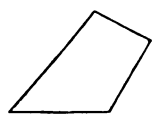
73 The line on which the perpendicular stands is called the Base, as A B,

74 And the long line subtended from the perpendicular to the base is the hypothenuse as C A.

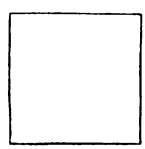
73 An acute angled triangle has all its angles acute, none of them being equal to 90 degrees.



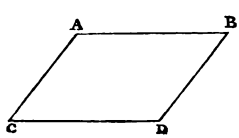
76 A space included within four sides is called a quadrilateral figure.



6 A square is a four-sided figure, having all its sides equal, and its angles right angles.



76 A rhombus (or lozenge) is a quadrilateral figure, having all its sides, and its opposite angles equal. Thus the angle A C D, is the same as the angle A B D, and the angle B A C, as its opposite angle C D B.



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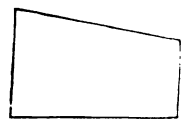
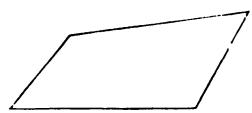
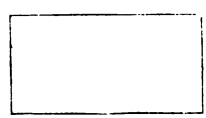
77 A trapezoid is a figure of four sides, having only tw
of its sides parallel.



77 A trapezium is a four-sided figure, unequal both i
its sides and its angles.



75 A parallelogram or rectangle, is a quadrilaterial figur
whose opposite sides are equal and parallel, an
whose angles are all right angles.



Figures of more than four sides are called Polygons
and when specified by the number of their sides
are thus designated.

75	A Pentagon has	5	sides,
74	Hexagon	6	„
74	Heptagon	7	„
75	Octagon	8	„
75	Nonagon	9	„
73	Decagon	10	„
77	Undecagon	11	„
74	Dodecagon	12	„

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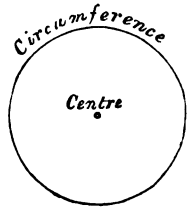
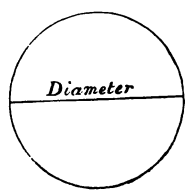
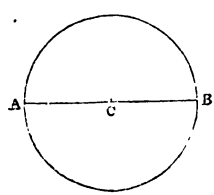
A circle is a plain figure contained within one line
73 called the circumference, which is every where equally distant from a certain point within it, called the centre.



73 The diameter of a circle, is a line passing from one side of the circumference *through the centre*, to the opposite side, and is the longest right line, that can
76 be obtained in a circle, which it divides into two equal parts called semicircles.



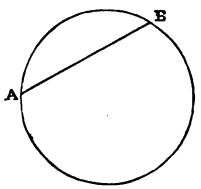
76 The radius of a circle is one half the diameter, or the length between the centre and the circumference. It is, in fact, the distance between the two legs of the compasses, taken for the purpose of striking a
73 circle, or arcs of a circle, for the intersection of lines.



In the above circle A C is the radius, being one half the diameter A B.

Page.

Every circle, great or small, contains 360° degrees, each degree being again divided into 60 equal parts called minutes, and in calculations in which more than ordinary exactitude is required, the minutes are subdivided into seconds, 60 of the latter being equal to one minute.



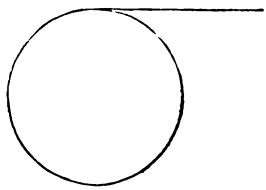
A chord of a circle, or rather the chord of an arc, is a *right line dividing* a circle into *two unequal parts*, and is thus the chord to either part of the circle: thus, in the above diagram, A B is equally the chord to the upper, as to the lower part of the circle; and that portion of the circle which is included between the chord and the circumference, is
76 called the segment of such circle.

76 A section is that part of a circle bounded by an arc and two radii.

73 An arc, is any part of the circumference of a circle.

In the problems which follow, the words "strike an arc," frequently occur: it will be seen that in almost all the cases, where it is intended that the arc should be cut by another, a very small one is required; and the pupil should exercise his judgment; for it often happens by making unnecessarily large ones, mistakes occur, caused by the work becoming confused.

Page.



76 The Tangent to a circle, or arc, is a right line drawn from one extremity of the circle, without cutting it.

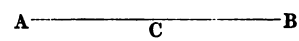
There are many other lines and properties of circles, but it is deemed needless to mention them here, as they are little required in Geometry, but fall more immediately under the head of Trigonometry.

STEPS TO THE MATHEMATICS.

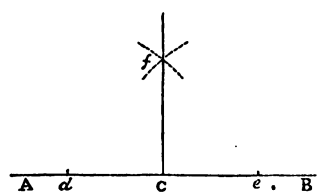
PROBLEM 1.

Page.
5 **To erect a perpendicular from a point upon a given right line, that point being at or near the middle of the line.**

3 Suppose the given right line to be AB.



The point from which the perpendicular is to be raised C.



Draw a similar right line AB.
Set the compasses on C;
from that point set off two equal distances as *d e*.
From the newly found point *d*,
9 with any radius greater than *d* C;
Describe an arc *f*.
From the point *e*,
with the same radius as *d f*,
describe another arc cutting *f*.
Draw a line from the point C
through the intersection of the arcs at *f*,
and the perpendicular is formed by the line C *f*.

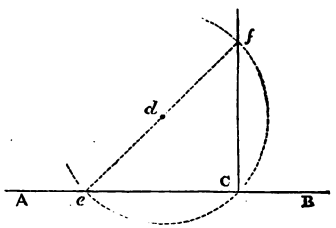
Great care must be observed in having a finely pointed pencil in the holder attached to the leg of the compasses, as also in drawing the lines, otherwise *serious errors creep* in.

PROBLEM 2.

Page.

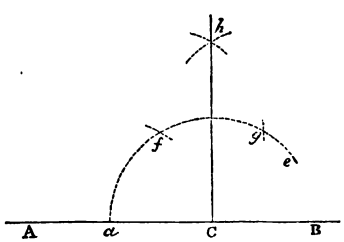
CASE I.

5 **To raise a perpendicular from a point given at or near the end of the line.**



Suppose the line A B;
The point whence the perpendicular is to be raised C.
Assume any point above the line as *d*,
9 with the compasses take the radius *d* C,
then from the point *d*
as a centre, sweep an arc cutting the line A B,
at *e*.
Observing that it minutely cuts through C,
continue the arc until it become in a right line with *e d*.
From the point *e*,
draw a line carefully through *d*,
until it intersects the arc at *f*.
A line drawn from C to *f*
will be the perpendicular required.

CASE II.

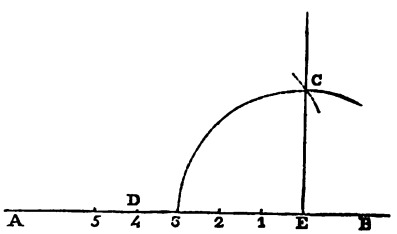


Suppose the line A B,
The point for the perpendicular C.

Page

With the centre C,
9 and any radius *c d*,
Describe an arc *d f e ;*
From the newly found point *d*,
with the same radius, on the arc *d f e*,
set off the distance twice, as at *f* and *g ;*
Now with the centre *f*,
and the same or any other radius, describe an arc as at *h ;*
With the centre *g*
and the last radius, intersect the arc at *h*.
A line drawn from C to *h*,
will be the perpendicular required.

CASE III.



15 By a scale of equal parts, on the line A B
set off five equal parts,
from the point where the perpendicular is required, say E.
With the centre E
and radius of three equal parts,
describe an arc as 3 C,
with the 4th. division for a centre as at D,
and a radius of five equal parts
intersect the arc at C.

Page.

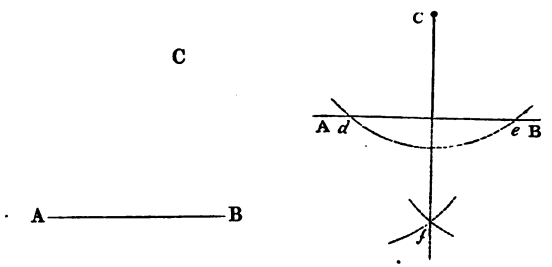
A line drawn through the intersection to the point E,
Will be perpendicular to the line A B.

Of these three methods the first is in most cases preferable; it might be finished even while accurately dividing the line A B. into the five parts required.*

PROBLEM 3.

CASE I.

To demit, or let fall, a perpendicular from a point to a line below.



Suppose it be required to draw a line from the point C,
perpendicular to the line A B;
in this case the point C,
being nearly above the middle of the line A B,
proceed thus:—
With the centre C,
and any convenient radius describe an arc
cutting the line A B,
in the points *d e*,

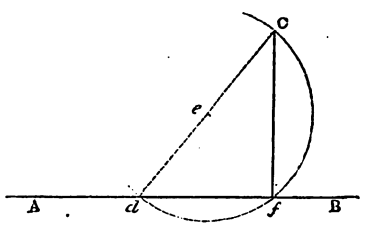
* If the pupil provides himself with a feather edged scale, of equal parts, he may frequently save himself much trouble; instead of taking by the compasses, the divisions required, and then laying them off separately on the line, he will have nothing farther to do, than to place the scale along the line given and with a fine pointed needle or pencil prick off the distances.

Page.

Then with the centre *d*,
and the same, or any other convenient radius, describe another arc as at *f*;
With the centre *e*,
and the same radius as last used, intersect the arc at *f*;
A line drawn from C,
towards *f*,
until it meets the line A B,
will be the perpendicular sought.

CASE II.

When the point from which the perpendicular is to be dropped, is nearly opposite to the end of the line.



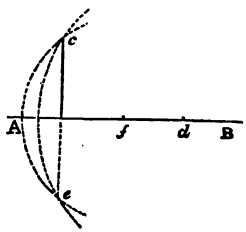
From the point C,
let it be required to demit a perpendicular to the line A B.

Draw a line from C,
4 at any convenient angle to line A B,
meeting the line at *d*;
18 Bisect the line C *d*,
at the point *e*;
then with the centre *e*,
and radius *d e*, or *e* C,
describe an arc cutting A B,
at f.

Page.

A line drawn from C to *f*,
will be the perpendicular required.

OR THUS.



From *d*,
or any point you like on A B,
with the radius *d* C,
describe an arc as C *e*;
Then from any other centre, as *f*, on line A B,
and with radius *f* C,
describe another arc intersecting the arc C *e*.
A line drawn from C,
to the point of intersection *g*,
will be the perpendicular sought.

76 Care should be taken to choose such radii for the arcs, as will prevent the intersections from being too oblique, otherwise the point not being clearly defined, an error might occur in the perpendicular; and for this reason, the first method in case 2nd is preferable.*

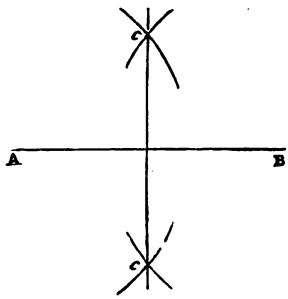
76 * These are the Geometrical methods of finding perpendicular lines, but they may be mechanically found by means of a protractor, or a square. A half-sheet of writing paper doubled down the middle, and then doubled again, so as to bring the folded edges together, also furnishes a ready means of raising a perpendicular.

In working Geometrical problems, few are more frequently called into operation than raising or demitting perpendiculars;—the pupil should therefore become thoroughly conversant with these simple problems, before he attempts to proceed with the more intricate.

PROBLEM 4.

Page.

73 **To bisect or divide a given right line into two equal parts.**



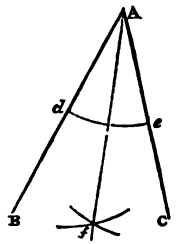
Let A B be the given line.
Place one foot of the Compasses for a centre on A,
and with any radius greater than half A B,
describe arcs above and below the line as *c c*;
then with the same radius, and centre B,
intersect the two arcs *c c*.
A line drawn from these points of intersection through the given line A B,
will bisect or divide it into two equal parts.

This is one of the simplest problems to define, yet one of the most frequent occurrence, being continually called into requisition.

Page.

PROBLEM 5.

4 **To bisect a given Rectilineal Angle.**



Suppose it required to bisect the angle B A C, or in other words to draw such a line from the vertex, as will divide it into two equal angles.

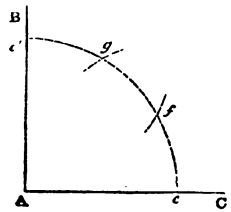
77 As a centre, place one foot of the compasses on the vertex A,
and with any radius less than either side A B, or A C, describe an arc as *d e;*
Then for a centre with one foot of the compasses on *d*, and with the last or any other convenient radius, describe an arc as at *f;*
With the same radius, and for a centre, the point *e*, intersect the arc *f*.
A line drawn from the vertex A,
through the intersection *f*,
will bisect the angle B A C.
For the angle B A *f*,
will be equal to the angle C A *f*.

For practice let the pupil draw angles of the following forms and bisect them.

Page.

PROBLEM 6.

77 To trisect a right angle, or to divide it into three equal angles.



Let it be required to trisect the right angle B A C.

With one foot of the compasses in the point A,
and with any convenient radius describe an arc as *d e*;
With the same radius, and *d*
for a centre, intersect the arc *d e*,
as at *f*.
With the same radius, and centre *e*,
again intersect the arc, as at *g*.
Lines drawn from the point A,
through the intersections *f* and *g*,
will trisect the angle.

This may either be performed or proved by the protractor, or scale of Chords, for as a right angle is equal to 90°, so when trisected, each angle will contain 30°.

By the Protractor.

76 Lay the feathered edge of the Protractor on the line A C,
observing that the centre rests exactly on the point A,
with a fine pointed needle or pencil, prick off 30° and 60° respectively.
Lines produced from the point A,
through each of these marks, will trisect the right angle, as before.

Page.

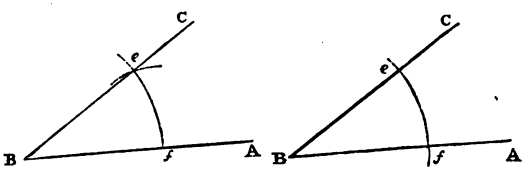
* *By the Scale of Chords.*

With the Chord 60° for a radius,
and with one foot of the compasses in the point A,
sweep an arc cutting A B, and A C.
Set off the Chord of 30°
on the arc from *d*.
With the same chord from *e*,
mark it off as at *f*.
Lines drawn from the point A, as before, will trisect the right angle, B A C.

Geometricians have laboured much to find a method of geometrically trisecting any other angle, than a right angle, but hitherto without success.

PROBLEM 7.

4 To construct an angle equal to any given Rectilineal Angle.



Suppose it required to construct an angle equal to the given angle A B C.

Draw at pleasure a similar line to B A;
9 With any radius, and with the centre B,
describe with the compasses an arc
which shall cut the two sides, B A, B C,

* A scale of Chords, will be found on all scales of dimensions given in the case of Mathematical instruments. It is generally marked Ch. on the scale.

Page.

as at *e f;*
Then from the point B,
(which is to form the vertex of the new Angle,)
with the same radius strike a similar arc;
Measure the arc *e f*,
and with that extent for a radius,
and one foot of the compasses at the intersection of the Arc on line A B,
cut the arc *e f*
as at *e*.
A line drawn from B,
through the intersection of the arc at *e*,
will give the Angle sought.

This problem also may be easily and expeditiously performed either by the Protractor or Scale of Chords.—If by the latter method, should the sides AB, and CB, be too short, extend or produce them at pleasure;*—then take on the scale of Chords 60° for a radius, and from the vertex B, strike an Arc,—do the same at B, on the line given for the new Angle, and then proceed as above.

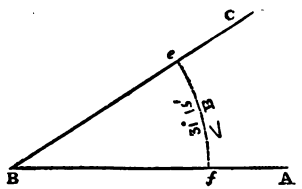
* The YOUNG Learner should remember that the length of the sides of an angle causes no difference in the angle itself.—For even if from the small scale in which the diagram is drawn as in the preceding page, the sides were to be produced to the extent of a mile, the angle would be the same.—For as the radius of *any* circle describes an arc of 60 or one sixth of the circumference, that portion or space between the two sides of the angle, from the vertex to the junction of the two sides by the arc described by radius 60 forms the angle; or rather, the distance or opening of the two sides as measured on the arc, denotes what portion of a circle is occupied by such division, whether large or small, whether extended through the realms of space, or confined to the diminutive diagram shown at the head of the problem.

The pupil for practice should form a number of angles, then ascertain their extent; and to prove if correct, take the dimensions, and set them off again as in Problem 9th.

Page.

PROBLEM 8.

10 **To ascertain the number of degrees contained in a given Angle.**



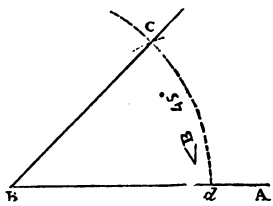
Let us suppose it be required to know what Angle the above diagram forms.

Take with the compasses, for a radius, on the line of Chords 60°;
for a centre, place one foot thereof on the vertex B,
sweep an arc that shall extend from side BC to BA,
as at *e f*;
then apply your compasses from *e* to *f*,
21 and that distance measured on the scale of Chords, will give the Angle, which, in the above example will be 31° 15′; and to illustrate the observation in the note on the opposite page, suppose B to be the junction of two roads;—now whether they continue in their respective directions only a few rods, or several miles, they still form an Angle of 31° 15′. Upon this system Railways, Turnpike roads, Canals, &c., are set out.

Page.

PROBLEM 9.

To make an Angle equal to any given number of degrees.



From the point B,
let it be proposed to set off two right lines to form an Angle of 45°.

Produce a line either from B to A, or B to C,
in this example say from B to A.
Take from the scale of Chords for a radius 60°
and with one foot of the Compasses in B,
describe an arc which shall cut B A,
as at *d*;
then on the line of Chords take the proposed Angle (45°)
and with one foot of the Compasses in *d*,
intersect the arc, as at C.
A line produced from B,
through the intersection at C,
will form the Angle required, viz. in this example, 45°.

Page.

Examples for Practice.

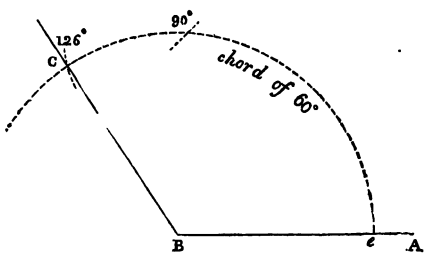
Describe respectively Angles of 26°; 33°; 48° 30′; 90° and 117°

5 The first, second, and third will of course form *acute* angles; the fourth a right angle; and the fifth an obtuse angle; see the definitions.

PROBLEM 10.

When the angles are constructed by the scale of Chords, and the extent exceeds 90° the number must be taken in twice: that is, after having struck the arc, with the chord of 60° measure off 90° on the arc, from the given line, (as described in the last problem,) from that point, the remainder.

For instance suppose it be required to set off an angle of 126° from line BA,
the vertex at B.



126°
90

36 remainder
or supplement.

It will be observed on reference to the above diagram, that on the chord of 60°, 90° are first taken, beginning at *e*.

Page.

Then by subtraction we find 36° more are wanting; these must be taken on the scale of Chords, and with one foot of the compasses on the arc, at 90° intersect the arc as shown at C.

A line drawn from B,

10 *towards*, *to*, or *through* C,

will give the angle required, viz. 126°.

If done with the Protractor, (which in practical work is more generally adopted by Surveyors,) lay the centre of the protractor on the point B,

so that the edge of the instrument rests on the line BA,

(and in this great care is needed;) then seek on the graduated edge the angle required, (in the foregoing example 126°) and with a fine pointed needle, prick off the same, draw a line from B,

through the dot, and the angle is formed.

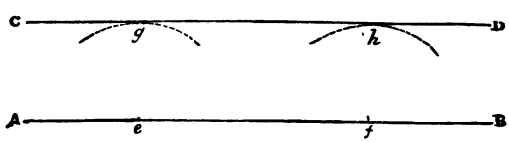
---

4 *Of Parallel Lines.*

These are usually drawn with an instrument called a Parallel ruler; but when one is not available, the following may be adopted.

PROBLEM 11.

3 To draw a right line which shall be parallel to a given right line.



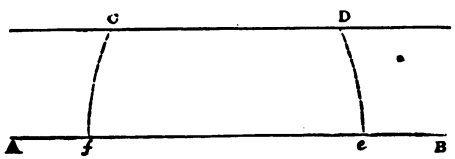
Page.

Let it be required to draw a line parallel to the right line AB.

From any two points on the line, as *e f*,
describe arcs of the extent required, as *g h*.
Draw the line CD,
so as just to touch the arcs without cutting them, and it will be parallel to the line AB.

PROBLEM 12.

When the Parallel line required is to pass through a given point.



Suppose it necessary to draw a line parallel to A B; and that the line is to pass through the point C.

CASE I.

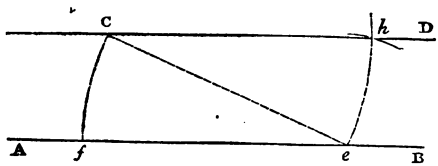
From any point as a centre on the line A B,
say at *e*,
with the radius *e* C,
describe an Arc from C to *f*;
With the same radius, and the centre *f*,
describe another arc from *e* towards D.
Measure the arc *c f*,

Page.

with the compasses, and set off the extent on the arc *e* D.
A line drawn from C to D,
will be parallel to the right line A B,
passing through the given point C.

CASE II.

Or it may be found thus.



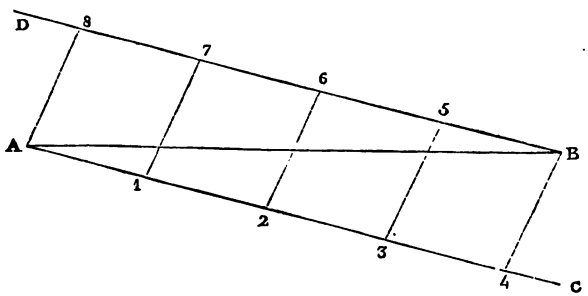
From the point C
75 Draw an oblique line to any part of A B,
as at *e*.
With radius C *e*,
and the centre *e*
describe an arc as *f* C;
then with the same radius, and the centre C,
describe another arc as *e h*.
Take with the compasses the extent of the arc *f* C,
and mark off the same distance on the arc *e h*.
A line drawn from C through *h*,
will be parallel to the line A B.
21 This is in fact, but a repetition of Problem 7th, the angle *e* C *h*,
being made equal to the angle *f e* C.

23 Quere? What is the angle?—(Problem 8th.)

Page.

PROBLEM 13.

To divide a line geometrically, into any number of equal parts.



It is required to divide the line A B into four equal parts, without the aid of a Parallel ruler.

From the point A,
75 draw an oblique line at pleasure, as AC;
from the point B,
draw another line B D,
21 making the same angle as B A C;
From A,
15 set off as many equal parts on line A C,
as the line A B,
is to be divided into.
Do the same on line B D, beginning at B.
(For the purpose of explanation these divisions are numbered in the diagram.)
Join 4.B. 3-5. 2.-6. 1.-7. A.8.
and so shall the line A B,
be divided into four equal parts.

Page.

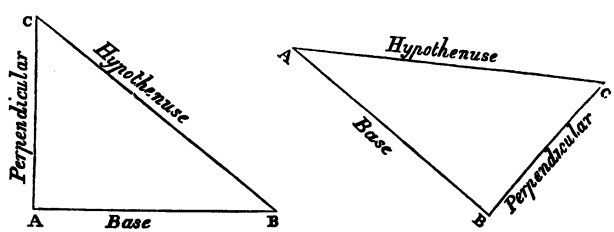
CASE III.

With the aid of a Parallel ruler, the same Problem may be performed much more easily and with greater expedition, avoiding the trouble of making the Angle, A B D :
requiring merely to set off the line A C,
at any convenient angle with AB.
Then setting off on line A C,
the required number of equal parts (4.)
With the parallel rule join 4.B,
And with the same parallel draw lines cutting AB,
from each division, 3, 2, 1.
The line A B,
will thus be geometrically divided into four equal parts.

The division may be also made, (though perhaps not with equal accuracy on a small scale,) by calculation and scale of equal parts. For instance, in the diagram before us, the line AB measures on a scale of 2 to the inch, 6.52 ; one fourth of which is 1.63.

PROBLEM 14.

To construct a right-angled Triangle.



5 It has already been shewn that a right Angle is formed by one line standing on another in a per-

Page

pendicular direction, or forming an angle (with the base) of 90°. The side joining the Perpendicular
74 to the Base is called the Hypothenuse.
Draw a line as A B,
13 Erect a perpendicular thereon as at A (or B).
Join by a line, the perpendicular and the Base, as at C B,
and the right angled triangle is formed.

When it is required that these should be of certain dimensions, recourse must be had to the scale of equal parts.
In the left hand figure before us, for instance, having the Base A B, 353, and the Perpendicular AC, 256, the length of the Hypothenuse is found 436, and
6 thus all three sides being unequal, it is a scalene triangle.
In the right hand figure, for the sake of variety, the perpendicular is raised from point B; hence A C is the hypothenuse;—and this also forms a scalene
6 triangle. It may here be observed, that had they been isosceles triangles, the perpendiculars being equal to the base, the property as a right-angled triangle would have been the same.
77 Triangles having the dimensions of each side given are easily constructed; one example will suffice.

PROBLEM 15.

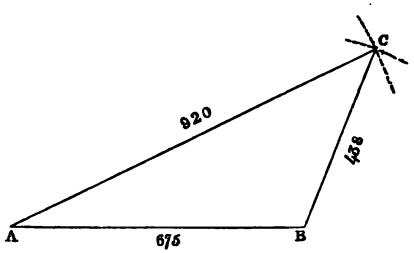
Having the dimensions of a triangle given, required the construction of the same.

Let the side A B, measure 675,
B C, „ 438,
A C, „ 920.

Draw the side A B,
at pleasure, and by the scale, set off its length, 675;
Then with the compasses, (on the scale,)

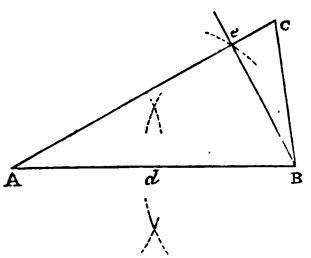
Page.

take the length of side BC;
and with centre B,
describe an arc, as at C.
Then with the dimensions of side, AC,
and centre A,
intersect the arc at C.
Lines drawn from A to C, and from B to C,
will give the triangle required.



PROBLEM 16.

In a given triangle, to draw a perpendicular from the vertex of either angle to its opposite side.



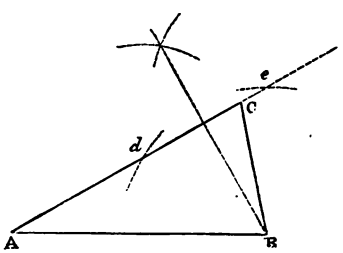
In the triangle ABC, let it be required to find the perpendicular from B, to its opposite side A C.

Page.

18 Bisect the side A B,
as at *d*.
With the radius A *d*,
and cehtre *d*,
strike an arc cutting A C,
as at *e*.
A line drawn from B to *e*,
will be the perpendicular required.

OR, BY PROBLEM 3.

15 In which case you would produce or extend the side A C,
and with any radius, and for a centre B,
would strike an arc cutting A C, at *d e*,
and continue as in problem 3rd.



This is an exceedingly useful problem, and simple as it is, is much required by Engineers and Surveyors in calculating the quantities of superficies, whether of triangles or of trapeziums. The area being found by multiplying the Base (A C,) by half the perpendicular B *e*.

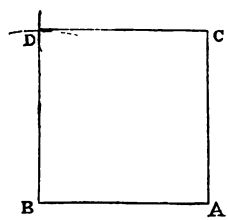
For practice, the pupil would do well to find the perpendicular from each vertex by each method. And all of the foregoing angles, might also afford examples for

Page.

practice, by measuring the base on any scale of equal parts, then finding the perpendicular by the last Problems, and with the compasses ascertaining its dimensions, and calculating the quantity as above.

PROBLEM 17.

7 **On a given right line to describe a square.**



Let AB, be the side of a Square.

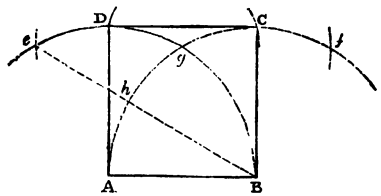
From the point A,
13 erect a perpendicular, and make it of the same length as side A B;
call this A C.
From the point C,
9 with the radius A B,
describe an arc as at D.
With the same radius, and B,
for centre, intersect the arc at D.
Draw lines from C to D, and from D to B,
and A B C D will form the square required.

The above is an extremely simple method, carrying reason in its process even to a child.

Page.

The following is sometimes adopted.

PROBLEM 18.



Let A B be the side of a square.

With the centre A,
and radius A B,
strike the arc *e* B.
Then with the same radius, and the centre B,
describe the arc A *f*,
intersecting the arc *e* B,
in *g*.
With radius *g* B,
and centre *g*,
define the exact point *e*.
Draw the line *e* B,
cutting the arc A *f*,
in *h*;
with radius A *h*,
and centre *g*,
intersect the arcs *e* B, and A *f*,
as at D and C;
By connecting the points AD, DC, and CB,
the square will be formed.

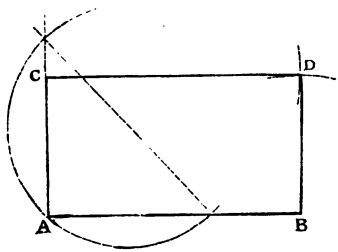
This, though occupying for the sake of clearness several lines in description, will be found very simple in operation, it is based on the principle
21 of making angles equal to another angle *e* BA.

PROBLEM 19.

Page.

On a given right line to construct a rectan-
8 gular Parallelogram.

Describe a rectangular Parallelogram whose sides shall be respectively—580 and 320*



On the given line A B,
set off by scale the length thereof 580.
13 Erect a perpendicular at either A or B;
set off the proper length thereof 320.
With the radius AB,
and centre *c*,
describe an arc as at D.
With the radius A C,
and centre B,
intersect the arc at D.
Join the points AC, CD, and DB, respectively, and so shall the Parallelogram be formed.

8 The pupil, by comparing the figure with the definition of a Parallelogram, will find that it forms a four sided figure, having its *opposite* sides equal, and its *angles* all *right angles*.
Thus, the two opposite sides AC, and BD,

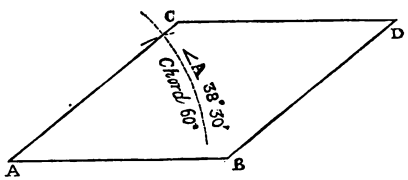
* In some instances, I have given dimensions to figures, in order that the pupil may accustom himself to taking them, although they do not strictly apply to that part of Geometry of which the work professes to treat.

Page.

are equal; as are also the opposite sides, AB, and CD,
and are parallel to each other.
A C is perpendicular to A B,
and so on of each angle.

PROBLEM 20.

7 **On a given right line to describe a rhombus, having the angle given.**



Given the side A B;
And the ∠ A 38. 30′.

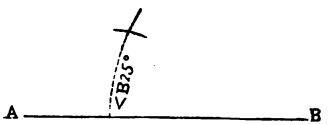
21 On the scale of Chords with radius 60°,
and centre A,
24 describe an arc. and proceed for the angle as in Problem 9th.
Having formed the angle,
take AB,
and set off the same length on AC.
Then proceed for the sides CD, and DB,
36 as in the last problem.
The sides AB, BD, DC, and CA, being respectively joined will form a Rhombus or four-sided figure, having all its sides equal, and opposite sides parallel, but the angles not right angles.—The angle
5 BAC being acute, and the angle ABD, obtuse.

For Practice.

Page.

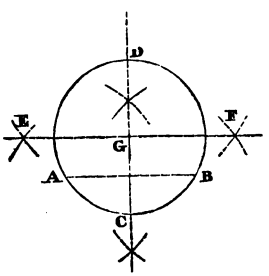
Describe a rhombus whose side is 735°, and angle A, 47°. 15′.

Describe a rhombus of the following side and angle.



PROBLEM 21.

To find the centre of a given circle.



In the circle draw a right line at pleasure as A B.

18 Bisect the line A B.

A line drawn through the arcs used for bisecting will give the perpendicular, C D,

or the diameter of the circle.

Bisect the line C D,

as E F.

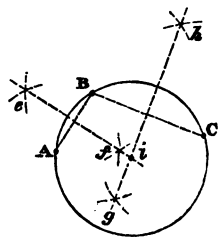
The point of intersection at G,

will be the centre required.

PROBLEM 22.

Page.

3 To describe a circle that shall pass through three given points not lying in a direct line.



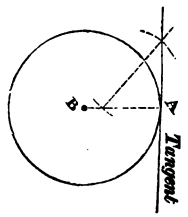
Suppose the three points, A B C,
and it is required to draw a circle that shall pass through them.

Connect the points AB and BC,
respectively.
18 Bisect the line AB, as *e f*;
Bisect the line BC, as *g h*;
produce these latter lines,
until they cross each other as at *i*,
which intersection *(i)* will be the centre of the circle.
Then with one foot of the compasses in *i*,
9 and with the radius, *i* A, *i* B, or *i* C,
describe a circle, and it will pass through
each point A B C.

PROBLEM 23.

Page.

11 **To draw a tangent to a given circle through a given point in the Circumference.**

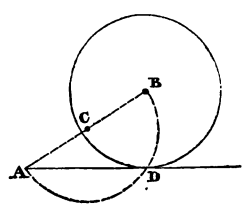


Let the above be the circle, and A the point on which the Tangent is to be drawn.

From the given point A,
draw a right line to the centre B.
At the point A,
13 erect a perpendicular to the line A B,
and it will be the tangent required.

PROBLEM 24.

When the given point is without the limits of the circle.



Let it be required to draw a tangent to the above Circle, from the point A.

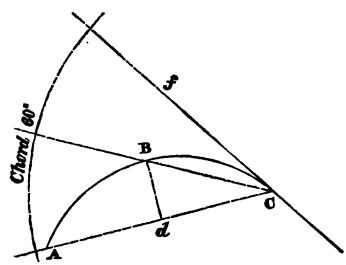
From the point A,
draw a line to the centre as A B;
18 Bisect the line A B,
as at C;

Page.

then with the centre C,
and radius A C,
describe an arc as A D B.
From the point of intersection of the arc,
with the Circumference as D,
draw a line to A,
and so shall A D,
be the Tangent required.

PROBLEM 25.

To draw a tangent to a point given in the arc of a Circle, the centre being unknown and inaccessible.



Given the arc A B C,
and the point for the tangent at C.

10 Draw the line (or Chord) A C,
18 bisect it as at *d*.
From *d*,
12 erect a perpendicular to* AC,
cutting the arc as *d* B.
Draw the chord B C.
21 Refer to problem 7th in order to make an angle

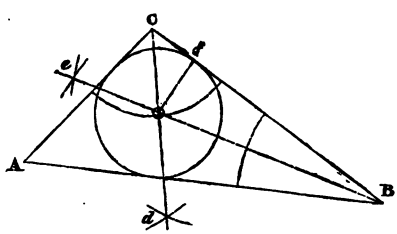
* The arcs used for bisecting give the perpendicular.

Page.

as B C *f*,
equal to the angle A C B.
Draw the line *f* C,
which will be the tangent required.

PROBLEM 26.

74 **To inscribe a circle within a given triangle.**

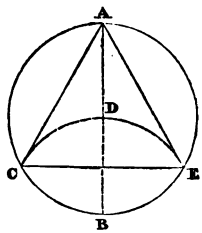


Given the triangle, A B C.
18 Bisect two angles, it is immaterial which,
suppose A C B;
and A B C;
from the intersection, ⊙
of the bisecting lines C *d*, and B *e*,
15 let fall a perpendicular to C B, or A B,
as at *f*;
then with the radius ⊙ *f*,
and centre ⊙
describe a circle, which will come within the limits of the triangle, and touch each side thereof.

PROBLEM 27.

Page.

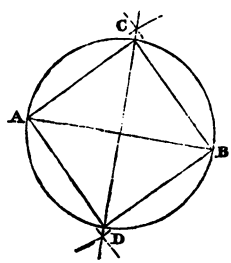
6 **Within a given circle to inscribe an equilateral triangle.**



9 Draw a diameter, as A B;
from B as a centre,
with the radius describe an arc C D E.
A line drawn from its point of intersection with the circumference, will give the side of the triangle, as C E;
Join E A, and C A,
and the equilateral triangle will be formed.

PROBLEM 28.

7 **To inscribe a square in a circle.**



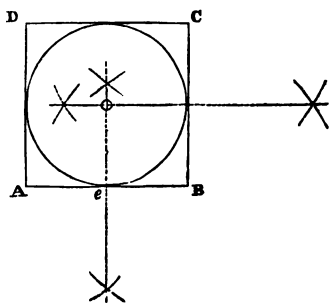
9 Draw the diameter A B;
18 Bisect the diameter as at C D;
Join the points AD, DB, BC, and CA,
and thus will the square be formed.

Page.

It is immaterial what direction the Diameter takes, so that it passes through the centre, otherwise of
9 course it would no longer be a diameter, but
10 merely a Chord of a circle.

PROBLEM 29.

To inscribe a circle in a square.

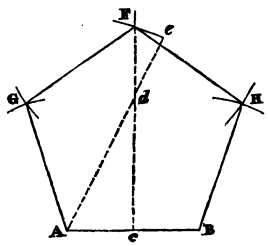


34 Describe a similar square as ABCD.
18 Bisect the line A B,
bisect the line, B C;
the point of intersection ⊙
will show the centre of the square.
Then with the radius ⊙ *e*,
which is one half of either side,)
and centre ⊙
describe a circle, which will be found contained within the limits of the square, so as to sweep each side thereof.

PROBLEM 30.

Page.

75 **Having one side given to describe a regular Pentagon.**



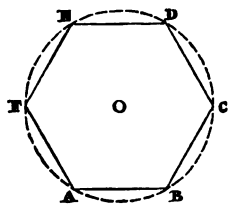
Suppose AB to be the side of a regular Pentagon.

18 Bisect A B,
as at C,
12 from which raise a perpendicular to A B;
with the compasses make the perpendicular of the same length as the base A B;
as at *d*.
Draw a line from A, through *d*;
then with the extent A *c*,
and from the point *d*,
set off *d e*;
then with the radius A *e*,
and for a centre A,
describe an arc intersecting the perpendicular,
as at F;
with radius A B,
and centre A,
describe an arc as at G;
with the same radius, and centre F,
intersect the arc at G,
and also describe one at H.
With the same radius and centre B,
intersect the arc at H;
draw the lines BH, HF, FG, GA,
and so will the Pentagon be formed.

PROBLEM 31.

Page.

8 To draw a regular Hexagon, having the dimensions of a side given.



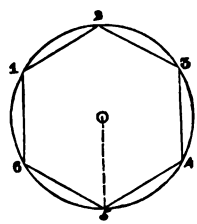
Let the side given be A B.

With radius A B,
and centre A,
describe an arc as at ⊙ .
With the same radius, and centre B,
intersect the arc at ⊙
this will give the centre of a circle,
on which the hexagon will be formed.
With the same radius A B,
and centre ⊙
describe a circle, on which set off
the length of the side A B,
six times, as AF., FE., ED., DC., CB.,
join the respective sides, and thus will a regular hexagon be formed.

PROBLEM 32.

Page.

8 **In a given circle, to inscribe a regular Hexagon.**

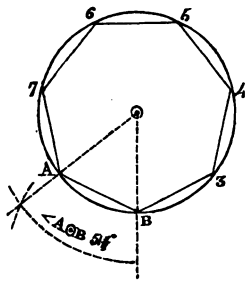


9 The radius of a circle being equal to the sixth part of the Circumference,—you have but to find the
38 centre of the given circle by problem 21st., and then by setting off the radius six times on the circle, as 1, 2, 3, 4, 5, 6, and by joining these points respectively, a regular hexagon will be formed.

PROBLEM 33.

Page.

8 **In a given circle to inscribe a regular Heptagon.**



If the centre be given as at ⊙
draw any radius, as ⊙ A.

10 It has already been observed that every circle contains 360°
which divide by the number of sides contained in the polygon required.

8 The above being a heptagon, divide 360° by 7,
which gives a quotient equal to $51\frac{3}{7}$,

24 then by Problem 9th with ⊙
for a centre, draw another radius making an angle of $51\frac{30}{7}$°
Draw the chord A B;
with the compasses take the extent thereof, and set it off 7 times, on the circumference,
as AB, 3, 4, 5, 6, 7;

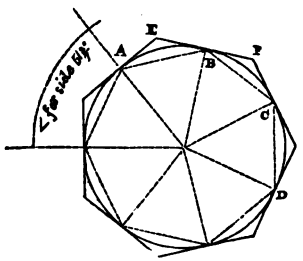
10 these points respectively joined by chords will form the regular heptagon required.

By the same rule any regular polygon may be inscribed in a circle, care being taken to divide the circumference 360° by the number of sides constituting the polygon.

PROBLEM 34.

Page.

To describe a regular polygon without or outside a given circle.



8 Suppose it required to describe a heptagon on the outer side of the circumference of the above circle.

48 By problem 33, inscribe a heptagon
within the circle;
from each angle as A B, C D, &c.
of the included heptagon,
draw a radius to the centre.

40 By problem 23rd, draw a tangent at the extremity of each radius,
and these tangents respectively meeting each other, will form the pentagon required.

For practical work it is more expeditious to use the Parallel Rule, thus: lay the rule on the points A C, and move it upwards till it reaches the point B, through which draw the line E F; do the same with the other sides, and the required polygon will be obtained.

The first method is an exceedingly tedious operation, occupying more than double the time a careful hand would take for the latter;—it will be observed also, that the situation of the polygon is changed, which in many cases may be a disadvantage, as it may be essential in some work that the side of the

Page.

polygon should have one extremity on a particular
48 point.—It has been objected to the use of the Parallel rule in this problem that without great care in drawing the line exactly on the circumference a segment of a circle may be made, and the polygon will thus be incorrect; this is true, but as a *per contra*, I would observe that unless the same care be taken in drawing the tangents, a similar result occurs

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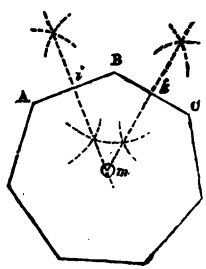
PROBLEM 35.

To find the centre of a given polygon.



8 Let it be required to find the centre of the above octagon.

18 Bisect any two sides, say, AB, BC,
as at *i k*,
by the lines *im*, *km*,
and the point of their intersection *m*, will be the centre.

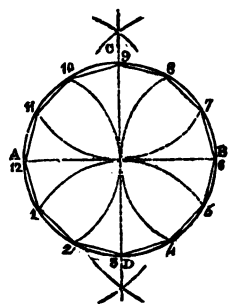
Should it be required to inscribe a circle in the polygon; proceed thus:
with one foot of the compasses in the centre,
and radius *mi*,
describe a circle.

To include the polygon in a circle:
with centre *m*,
and radius *m* A,
describe a circle which will include the polygon.

PROBLEM 36.

Page.

To describe a Dodecagon, or to divide a circle into 12 equal parts.



9 Draw the diameter, A B,
18 bisect it as C D;
then with the radius of the circle,
and for centre, respectively AB, CD,
describe arcs passing through the centre,
and cutting the circumference, as at 1, 2, 3, &c.,
which will be the points of division required.
Chords drawn to these intersections respectively, will give the dodecagon.

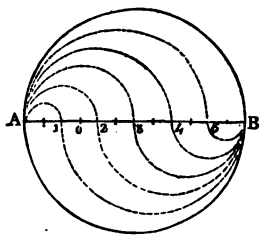
For practical use it will be unnecessary to describe the arcs as in the diagram; it will be sufficient merely to shew the cuttings on the circle.

48 This problem can also be worked as problem 33.

PROBLEM 37.

Page.

75 To divide a given circle into any proposed number of parts, equal both in area and perimeter.



Suppose it required to divide the above circle into six equal parts.

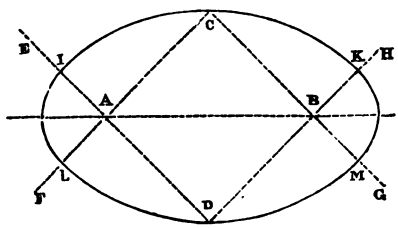
Draw the diameter AB;
by any scale of equal parts, divide it into six equal parts as 1, 2, 3, &c.
29 or it may be done by problem 13th., which, when the diameter is small, will be the more correct method;
or for the purpose of striking semicircles, it would be as well, to divide the diameter into double the number of parts proposed.
Then with half the distance between A 1,
as a radius, and centre,
describe on one side of the diameter,
a semicircle as A 1;
repeat the same operation at B 5,
but on the opposite side of the diameter.
Then with radius, A 1,
and centre 1,
describe a semicircle as A 2;
repeat the operation on the opposite side as B 4;
then for a centre, half the distance between A 3,
as at *o*;
with the radius, A *o*,
describe a semicircle as A 3.
Repeat the same operation on the opposite side as B3.

Page.

Then with radius A 2,
and for a centre, 2,
describe the semicircle A 4;
with the same radius,
and for a centre 4,
describe the semicircle B 2,
and thus shall the corresponding semicircles divide the given circle into the proposed six parts.

PROBLEM 38.

To describe an Ellipse of indefinite dimensions.

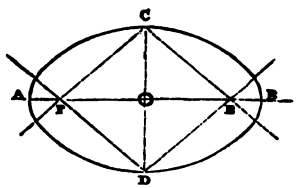


Draw a line as A B,
77 (which may be called the transverse diameter; a line passing through the centre from C D,
73 is called the conjugate diameter.)
upon which form a quadrangle as ABCD, thus:
18 Bisect the line A B,
as at C D;
extend each line of the quadrangle as EF, GH;
then with centre D,
and radius D C,
describe the arc I K;
with the same radius,
and centre C,
describe the opposite arc L M;
now with centre A,
and radius A L,
describe the arc L I;
with the same radius,
and centre B,
describe the opposite arc M K,
and thus will the ellipse or rather oval be formed.

PROBLEM 39.

Page.

77 To describe an ellipse having the transverse
73 and conjugate diameters given.



Suppose an ellipse be required, having the transverse diameter AB, 2.35, and the conjugate diameter, CD, 1.50.

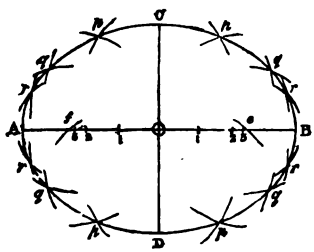
Draw the transverse diameter by scale as A B;
bisect it with the conjugate CD,
observing to retain an equal dimension on each side of the transverse, (viz. in this example, $\frac{2}{1.50}$ cutting it as a centre at ⊙.
With radius A ⊙
and centre D,
describe an arc cutting A B,
in E E,
74 which points will be the foci of the ellipse.
Form a Quadrangle as CE, DE,
53 And then proceed as in the last problem.

These methods form as near an approximation to an ellipse as practical work may require, but they are not mathematically true. A more correct but more tedious method will be found in the following problem.

PROBLEM 40.

Page.

Having the transverse and conjugate diameters given, to construct an ellipse by consecutive points.



With centre D,
and radius A O,
cut A B
in *e f*.

74 For the foci of the ellipse,
beginning at ⊙ divide A ⊙
into any number of parts, (the greater the number, the more correct the operation) observing to diminish the distance gradually between each, as you approach towards A,
as in the diagram marked 1, 2, 3, &c.

With radius A 1,
and centre *e*
describe the two arcs on the left of the conjugate, marked *p*.
With radius B 1,
and centre *f*,

73 describe the two arcs on the right of the conjugate, also marked *p*.
With centre *e*,
and radius B 1,
intersect the arcs on the right at *p*;
with the same radius, and centre *f*,

Page.

intersect the arcs on the left.
With centre *e*,
and radius B 2,
describe arcs on the right;
and with the same radius, and centre *f*,
describe arcs on the left.
With radius A 2,
and respective centres *e f*,
intersect the arcs as at *g*.

Then with radius A 3,
and centre *e*,
describe arcs as at *r*.
With radius B 3,
and centre *f*,
intersect the arcs.

In this manner proceed with as many divisions as you choose to make on the transverse diameter.

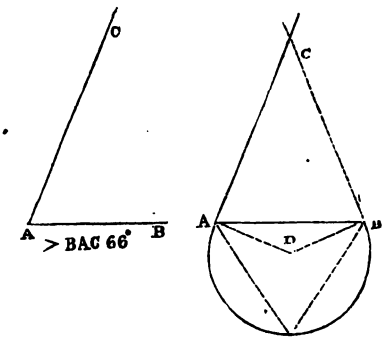
Then with a steady hand (or with the help of a piece of card forming the segment of a tolerably large circle, connect the points of intersection, *a*, *r*, *q*, &c.

The protractor usually included in a case of instruments will be a good guide for the hand.

PROBLEM 41.

Page.

76 **On a given line to describe the segment of a circle, capable of containing a given angle.**



Suppose the given line A B,
the angle B A C 66°

Required the segment of a circle that shall contain the same angle, viz: 66°

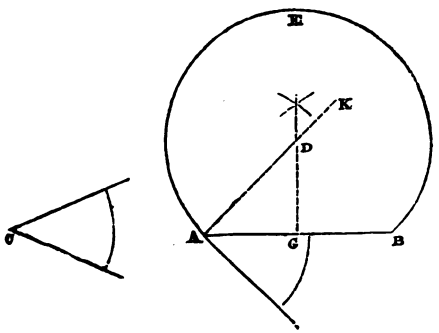
24 Make ∠ ABC, equal to ∠ BAC;
on points A and B,
erect perpendiculars cutting each other,
13 as at D;
then with radius D A,
and centre D,
describe an arc as ABE,
which will be the segment of a circle, capable of containing the angle proposed, viz: 66°
the ∠ A E B
being equal to the ∠ B A C.

PROBLEM 42.

Another Method.

Page.

On a given right line to describe an arc of a circle that shall contain an angle equal to a given angle.



At the point A,
in the straight line A B,
make the angle, B A F,
21 equal to angle C.

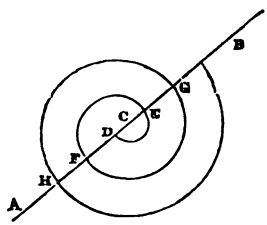
At the point A,
erect the line A K,
13 at right angles to A F.
18 Bisect A B,
by the perpendicular G D,
cutting A K,
in D,
which will be the centre of the circle of which the
10 segment is required.
Then from the centre D,
with the radius D A, or D B,
describe the arc A E B,
which shall contain the given angle.

NOTE. As all the angles in the same arc of a circle are equal, lines drawn from *any* point in the arc A E B, to the extremities of the line A B, will contain the required angle.

PROBLEM 43.

Page,

76 **To draw a spiral line from a given point.**



Suppose C the point on which a spiral line is required.

Draw the line A B,
through the point C;
then with any radius* and for a centre C,
describe a semicircle on either side of line A B,
as D E;
then with radius D E,
and centre D,
describe another semicircle on the opposite side of the line as E F.
Return to centre C,
and with radius C F,
describe the semicircle F G;
with radius F G,
and centre D,
describe the semicircle G H,
and so continue, (ad libitum) alternately shifting the centre from C to D.
The former point being the centre for all the semicircles on the right of the line, and the latter for those on the left.

* The radius will of course depend on the dimensions of the spiral proposed, and the direction of the spiral must be regulated according to the work intended.

PROBLEM 43.

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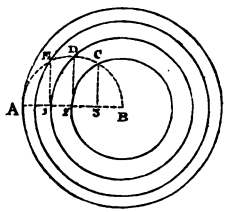
73 **To divide a circle into any number of equal parts, by concentric circles.**



Let it be required to divide the above circle into four equal parts.

Draw the radius A B,
which divide equally into four parts, 1, 2, 3.
This may be done either by a scale, or by problem
29 13th.
At each of these points raise perpendiculars to the radius, A B.
(Having raised one perpendicular, the others may be drawn by the parallel rule.)
Then bisect or take half the radius, A B,
(which in the above example falls at 2,
the radius being divided into 4 equal parts.)
Describe a semicircle from A to B;
the points of intersection of the perpendiculars with the semicircle, as at 1 E, 2 D, 3 C,
will form radii from B,
for the required circles.
Thus with centre B,
and radius B C,
describe a circle;
then from the same centre, and radius B D,
describe another circle,
and so on for the number required.

PROBLEM 44.

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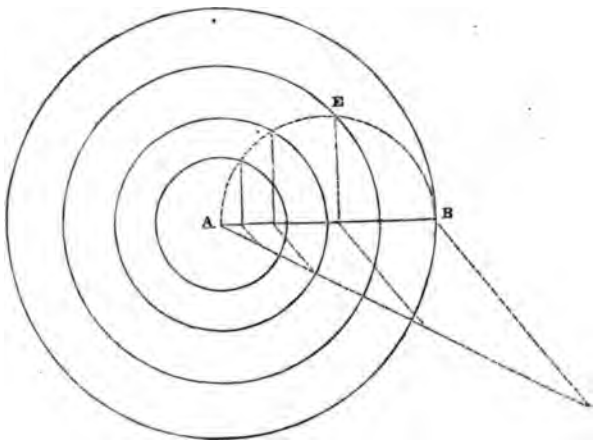
73 The foregoing problem is also applicable to the division of a circle into proportional concentric circles.



Thus, let the above circle be divided into four parts, bearing such proportion as 1, 2, 4, 6, having the smallest near the centre.

Draw the radius A B,

29 then by problem 13, divide it into the proportional parts required.

In the above, the first part is taken as 1-6th of an inch, the second 1-3rd., the third 2-3rds., and the last 1 inch,—I have let the work remain that the practical application of the quoted problem may be seen.

Having now found the proportional divisions of the

60 radius, proceed as in the last problem, viz., raise perpendiculars from each point;

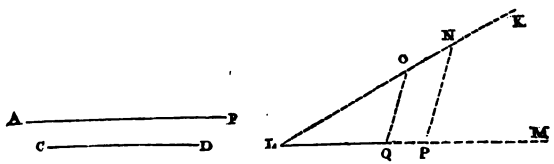
then bisect the radius A B,

Page.

draw the semicircle A E B;
and from the centre A,
with the intersection of each perpendicular,
severally with the semicircle,
describe circles; these will bear the relative proportion required.

PROBLEM 45.

To find a third proportional to two given lines.



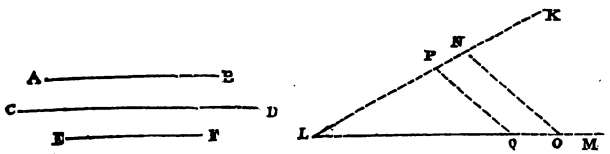
Given the lines A B, and C D,
Required a third proportional, or in other words, required a line, that shall bear the same ratio
76 to C D,
as C D, does to A B.

Construct an angle, at pleasure, as K L M;
from the vertex L,
set off on L K,
the length of the given line A B,
as at L N;
and on L K, and L M,
set off the given distance C D,
as at O, and P;
join N P,
and with a parallel rule draw
a line from O,
parallel to N P,
as O Q;
then L Q, shall be of the same proportion to C D, as C D, is to A B.

PROBLEM 46.

Page

To find a fourth proportional to three given lines.



Given the lines A B, C D, E F,
required a fourth line, which shall bear the same proportion to E F, as C D, does to A B.

Make any angle at pleasure as K L M;
set off on L K,
the length of line A B,
as at L N;
on L M,
set off the given length C D,
as at L O.
Join N O;
then on L K,
set off a distance equal to E F,
as at L P;
and from this point draw a line
parallel to N O,
as at P Q:
thus will L Q:
be the fourth proportional required: as it will bear the same proportion to E F, as C D, does to A B.

This is a most pleasing and instructive problem, and may be rendered applicable to the solution of many arithmetical questions, particularly in sums in proportion, and may be read as such sums are, viz., as A B, is to C D, so is E F, to L Q.

Both for amusement and instruction, the pupil might set himself a few questions, and resolve them

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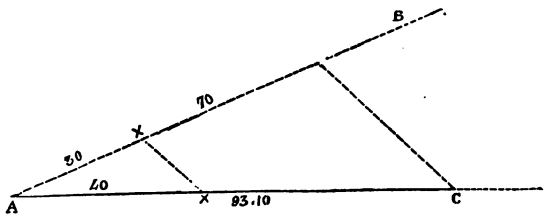
geometrically and arithmetically. I have often thought, if young people could be made to believe there is amusement to be found in this study, how much they would really experience, by seeking it; and were two or three to sit down, as at a game of forfeits, and work out this and similar problems, and prove them by arithmetic, there would be not less excitement, and far more entertainment derived, than from some of the foolish games that generally interest them. For instance a simple question thus:

If 30 articles cost £40., what will 70 cost?



Articles. Articles. £.
30 ——— 70 ——— 40
40

3.0) 280,0

£93. 10.

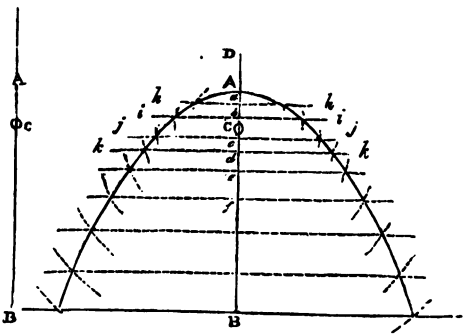
From the scale of equal parts, are set off on A B,
the number of articles *for which the price is required*, viz. 70.
and the number obtained for a certain price, viz, 30.
Also on line A B.
From the same scale, the price given, £40 on A C;
it will be immediately seen, that
these two points 30 and 40,
being joined, a proportion is at once established, which by means of the parallel rule, may be continued from the point 70 to C,
which line A C, will be found to measure 93½.

Shewing that if 30 articles cost £40.
70 will cost £93. 10.

PROBLEM 47.

Page.

74 The axis, and focus given, to describe a
75 Parabola.



Given the axis A B,
and focus C.

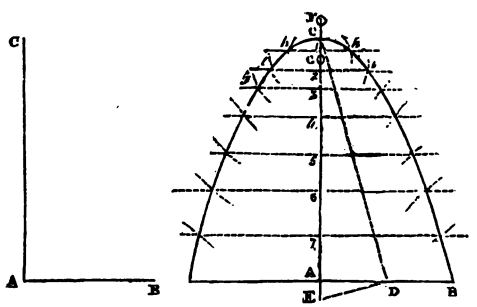
Extend the axis from A to D,
making AD,
equal to the space between the focus C and A;
set off on the axis A C,
any number of divisions, the more you take, the
55 more correct will be the result, observing (as in
the ellipse) to have them closer, nearer the focus,
as *a b c d e* &c.
Through each of the these points draw
12 perpendiculars to the axis.
Having drawn one perpendicular, the others may be
constructed by the parallel ruler.
With the centre, (the focus) C,
and radius D *d*,
cut the first perpendicular (that is, the one nearest
the point A,
right and left of the axis as at *h h*;
with radius *b* D,
and centre C,

Page.

cut the 2nd perpendicular, in the same manner as the 1st. at *i i;*
then with radius *c* D,
and centre C,
cut the next perpendicular as at *j j;*
and in this way proceed with each division and perpendicular, observing always to use the focus as the centre.
With the greatest exactness, commencing the curve at A,
continue it through each of the cuttings, *h h, i i, j j,*
and thus will the parabola be formed.

PROBLEM 48.

75 73 To construct a parabola, having the abscissa
75 and ordinate given.



Let the abscissa be A C,
and the ordinate A B.

18 Bisect the given ordinate A B,
as at *d;*
join C D,
and from the extremity D,
13 raise a perpendicular towards the abscissa, which extend, or produce until it meets

Page.

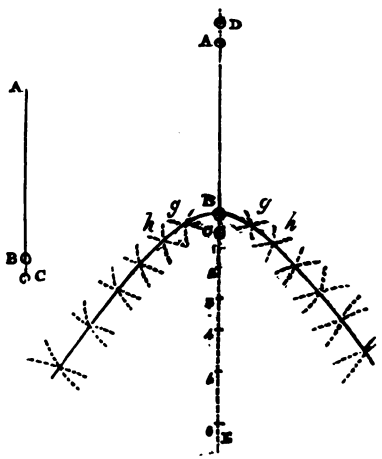
the perpendicular, as at E.
With the compasses take the extent A E,
and produce the abscissa from C,
equal to A E,
as at C F;
set off the same extent, on the abscissa,
below C,
as at G,
74 which will be the focus of the parabola.
Set off any points on the abscissa, observing the
65 remark in the previous problem, as 1, 2, 3, 4, &c.,
75 through which draw double ordinates at pleasure,
parallel to A B.
This may be done with the parallel ruler, or in the
26 absence of which have recourse to problem 11th.*
Then with radius I F,
and for a centre the focus G,
cut the first double ordinate as at *h h*;
with radius 1 F,
and centre G,
cut the next double ordinate at *i i*;
with radius 2 *f*,
and centre G,
cut the next ordinate as at *j j*,
aud so continue, in the same manner as in the last
problem.

* When the parallel ruler is not at hand, perpendiculars may be raised, by laying a flat scale along the base line, and with a piece of wood or ivory, forming a right angled triangle, placed closely against the base, carefully sliding the triangle along the flat scale to the points required, a line drawn aiong the edge of the triangle will be the perpendicular sought.

PROBLEM 49.

Page.

74 **The transverse axis, and the interior focus given to describe an Hyperbola.**



Suppose the transverse axis A B,
And the interior focus C.

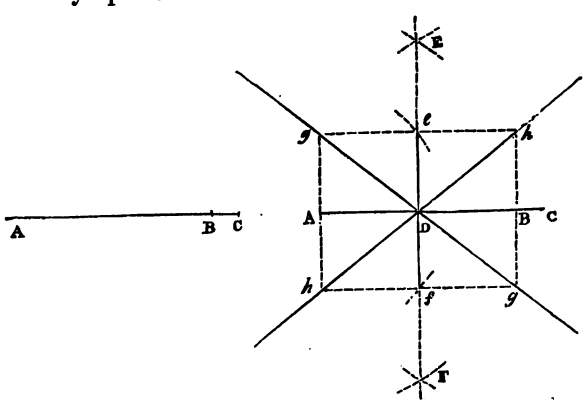
Extend the axis, as in the dotted lines,
and make A D,
equal to B C;
thus will A D,
be the exterior focus.
On the dotted line B E,
set off any number of points as in the instructions
65 for the parabola, as 1, 2, 3, 4, &c.
Then with radius B 1,
and for a centre, the interior focus C,
describe arcs as at *g g*;
with radius A 1,
and for a centre, the exterior focus D,
intersect the arcs, *g g*,

Page.

and thus will the points be found for the first curve.
With radius B 2,
and centre C,
describe arcs as at *h h*;
with radius, A 2,
and centre D,
intersect the arcs at *h h*,
and thus continue alternately taking for a centre, the interior focus, and smaller radius, and the exterior focus, with the larger radius.
With the hand carefully join the respective points, and thus will the hyperbola be formed.

PROBLEM 50.

73 **The transverse axis, and the interior focus being given, to find the conjugate axis, and the asymptotes.**



77 Given the transverse axis, A B,
74 and the interior focus C,
73 required first the conjugate axis.

18 Bisect the transverse A B,
as E D F;

Page.

with radius D C,
and centre A,
cut the perpendicular as at *e f*,
which will give the conjugate axis.

Required the Asymptotes.

8 Construct a rectangle by drawing
from each extremity of the axis A B;
a line parallel to *e f*;
and from *e* and *f*,
lines parallel to the transverse axis A B,
draw diagonal lines through the rectangle, intersecting each other in D,
Which lines will be the asymptotes required.

Thus in the above diagram,

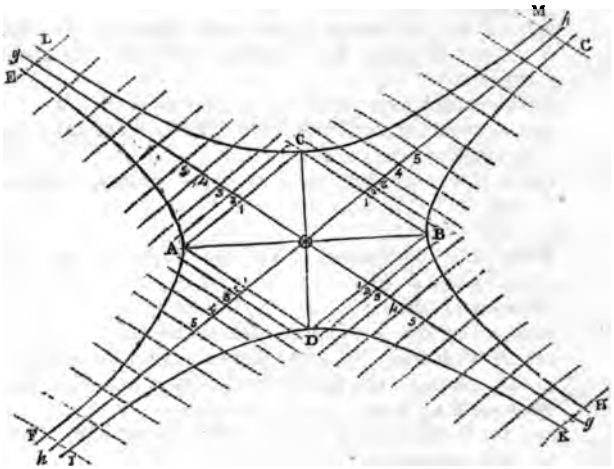
g g, *h h*,	are the asymptotes,
A B	the transverse axis,
e f	the conjugate,
and C	the interior focus.

This problem is preparatory to the following.

PROBLEM 51.

Page.

Given the axis, (transverse and conjugate) and the curve of an hyperbola, to describe the opposite hyperbola, and the conjugate hyperbola.



In the above diagram are given,
The transverse axis A B,
the conjugate axis C D,
and the curve of an hyperbola E A F.

Required the opposite hyperbola, and the two conjugate hyperbolas.

70 Proceed as in the last problem, that is, first find the asymptotes, by constructing a rectangle, and drawing diagonal lines, as in the last example; thus will $g\,g$, $h\,h$, be the asymptotes.

Page.

Now set off, on each asymptote, as many divisions, as you may judge expedient for accuracy, observing to have them closer, near the focus.

This may be easily done, in one operation, by placing the compasses at the intersection of the asymptotes ⊙;

and keeping it as a centre, mark on each asymptote, the first division, as 1, 1, 1, 1.

Extend the compasses to the point fixed on for the second division, for a radius, and with the same centre ⊙

mark on each asymptote the second as 2, 2, 2, 2,

and so continue until you have divided them into the number of parts decided on.

Draw lines through each of these points, parallel with A C, C B, &c.,

as *i i*, *j j*, *k k*.

With the compasses take the distance on the asymptote *g* ⊙

between 1, and F;

and on the first division of each asymptote,

set off with care, the same distance, right and left;

in like manner take the space on the second division between 2 *i*,

and set it off, right and left, on the second line,

on each asymptote;

continue thus throughout,

With a fine pointed pencil, trace curves from each point respectively, and thus will the hyperbolas be formed; that is to say,

The opposite hyperbola, will be G B H,

and the conjugate hyperbolas, (or those described on the conjugate axis) I D K, and L C M.

GLOSSARY.

L denotes the word to be of Latin derivation: G, of Greek.

Abscissa, *ab* from, and *scindo*, *scissus*, L, to cut. Part of the Diameter of a Conic Section intercepted between the vertex and semi-ordinate. For the Plural, some Mathematicians use the Latin Abscissæ; some the English, Abscissas.

Acute, *acutus* L, sharp.

Angle, *angulus* L, a corner.

Arc, *arcus* L, a bow.

Area, *area* L, a court yard, an open space.

Asymptote, a (*a*) not, συν (*sun*) together, and πιπτω *(pipto)* to fall, G, which never meet; incoincident. Asymptotes are straight lines which approach nearer and nearer to some curve; but which, though they and their curve were infinitely continued, would never meet; and may be conceived as tangents to their curves at an infinite distance.

Base, βασις (*basis*) G, a foundation or bottom.

Biquadrate, *bis*, twice, and *quadratus*, L, squared.

Bisect, *bis* twice, *seco*, *sectus*, L, cut. Hence, bisect signifies to cut in two. In Geometry it means to halve.

Centre, *centrum* L, the centre.

Chord, χορδμ (*chorde*) G, the string of a lute.

Circumference, *circum.* L, around, *fero* to carry.

Complement, *con* and *pleo* L, to fill up.

Concave, *concavus* L, hollow.

Concentric, *con* together, and *centrum* L, the centre, having the same centre.

Cone, κωος (*konos*,) G, a cone.

Conic, from the same, relating to a cone.

Conjugate, *conjugatio* L, a yoking or joining together. The conjugate diameter, is a diameter at right angles to the Transverse.

Convex, *convexus* L, vaulted, rising in a circular form.

Cube κνβος (*kubos*) G, a cube; a regular body with six equal square sides.

Curve, *curvo* L, to bend, to bow.

Cylinder, κυλινδρος *kulindros* G, a roller.

Decagon, δεκα (*deka*) ten, and γωνια (*gonia*) G, a corner, a figure with ten angles.

Diagonal, δια (*dia*,) G, through and γωνια *(gonia)* a corner, a line drawn across a polygon from corner to corner.

Diameter, δια *(dia,)* through and μετρον *(metron)* G, a measure: a line passing through the centre of a curved figure.

Dodecagon, δωδεκα (*dodeka*) twelve, and γωνια (*gonia*) G, a corner; a figure having twelve angles.

Dodecahedron, δωδεκα (*dodeka*) twelve, and εδρα (*edra*) G, a seat; a solid body contained under twelve equal pentagonal faces.

Ellipse, ελλειψις (*elleipsis*) G, a deficiency.

Equator, *æquus* L, equal, alike.

Equilateral, *æquus* equal, and *latus* L, a side, equal-sided.

Evolve, *evolvo*, L, to unroll.

Extremity, *extremus*, L, the utmost point.

Finite, *finitus* L, bounded, limited.

Focus, *focus* L, a hearth, a fire place. The plural in Latin is foci. Some Mathematicians Anglicise it, and make the plural focuses.

——— The focus of an *Ellipse* is a point towards each end of the transverse diameter, or major axis, from which if two lines be drawn to any point in the circumference, their sum will be equal to the major axis. (Harris.)

——— The focus of a *Parabola* is a point in the axis, within the figure, and distant from the vertex by a fourth part of the parameter. (Harris.)

——— The focus of an Hyperbola is a point in the principal axis, within the opposite Hyperbola, from which if any two right lines are drawn, meeting in either of the opposite Hyperbolas, the difference will be equal to the principal axis. (Harris.)

Frustum, *frustum*, L, a fragment, a broken piece: thus the frustum of a cone, or pyramid, is the portion left after the top is cut off by a plane parallel to the base; the frustum of a sphere is the portion left in the middle, after two pieces have been cut off by parallel planes. From some unaccountable cause, this word is almost universally spelt frustrum.

Geometry, ημ (*ge*) the earth and μετρον (*metron*) G, a measure.

Hemisphere, ημισυς (*hemisus*) half and σφαιρα (sphaira) G, a sphere, the half a globe.

Heptagon, επτα (*hepta*) seven, and γωνια (*gonia*) G, a corner; a plane figure having seven angles.

Hexagon, εξ (*hex*) six, and γωνια (*gonia*,) G, a corner; a plane figure having six angles.

Horizontal οριζω (*orizo*) G, to limit.

Hyperbola, υπξε (*uper*, *hyper*) beyond, and βλλω (*ballo*) G, to throw; a section of a cone made by a plane, which, if continued, or thrown beyond, would pass into the opposite cone.

Hypothenuse, υπο (ups, hypo,) under, and τειvo (teino) G, to stretch; the subtense: the line that subtends the right angle of a right angled triangle.

Infinite, *infinitus* L, unlimited, without end.

Inscribe, *inscribo* L, to write in. Applied Geometrically, it signifies to draw a figure within another; thus (page 42) a circle is inscribed within a triangle.

Intersection, *inter*, between, *sectus*, cut, L; the point where two lines cross each other.

Isosceles, ισος (*isos*) equal, σκελος (*skelos*) G, a leg; a triangle having two legs, or sides, equal.

Line, *linea* L, a line.

Lozenge, *losange*, French, a four corned figure.

Mathematics, *μαθηματοκη* (*mathematics*) relating to learning, from *μαθημα* (*mathema*) G, learning, or science. The science which contemplates whatever is capable of being numbered or measured.

Mechanics, *μηχανη* (*mechane*) G, a machine. That branch of practical mathematics which treats of the effects of powers or moving forces, and applies them to machines, or engines. (Maunder's Treasury.)

Mensuration, *mensura* L, a measure. The art of measuring lines, superficies, solids, and angles. The latter branch generally goes under the specific name of Trigonometry.

Momentum, *momentum* L, weight, force. In mechanics it signifies the weight of a body multiplied into its velocity. Thus, suppose two cannon balls to strike a fortress. If the larger ball weigh five times as much as the smaller, and fly from the cannon with four times the velocity, then it will strike the wall with twenty times the momentum of the smaller ball.

Motive Power. Motus, L, moved. In mechanics, the power or force acting upon any body, or quantity of matter, by which it is put in motion. (Maunder.)

Multilateral, *multus*, plural *multi*, many, and latus, a side, L, many sided: applied to polygons.

Nonagon, *nonus* ninth, L, and *γωνια* (*gonia*) a corner, G; a plane figure with nine angles.

Octagon, *οκτω* (*octo*) G eight; and *γωνια* (*gonia*) G, a corner: a plane figure with eight angles.

Oblate, *ob* against; *latus*, the side L; a term applied to the spheroid formed by the rotation of an ellipse about the shorter axis. The earth is an oblate spheroid, being flattened at the poles: Jupiter is still more so.

Obtuse, *obtusus* L, blunted.

Oblique, *obliquus*, L, indirect.

Ordinate, *ordino* L, to put in order. A line drawn perpendicular to the axis of a curve, and terminating the curvilinear space. (Bp. Berkeley.)

Oval, *ovum* L, an egg. An ellipse is often termed an oval, from its egg like shape.

Parabola, *παρα* (*para*) beside; and *βαλλω* (*ballo*) G, to throw. A conic section, formed from cutting a cone by a plane parallel to one of its sides.

Parallel, *παρα* (*para*) G, beside and *αλλμλων* (*alleoln*) each other.

Parallelogram, the same as for parallel; and *γρμμα* (*gramma*) G, a letter.

Parallelopipedon, the same as for parallel; and *επι* (*epi*) G, upon; *πεδον* (*pedon*) the ground.

Parameter, *ωαρα* (*para*) beside and *μετρον* (*metron*) G, a measure.

Pentagon *πεντε* (*pente*) G, five, and *γωνια* (*gonia*) a corner; a plane figure with five angles. Perpendicular, *per* L, through; and *pendeo*, to hang.

Perimeter, *περι* (*peri*) G, around and *μετροο* (*metron*) a measure: the compass, or sum of all the sides which bound any figure, whether rectilinear or mixed.

Periphery, *περι* (*peri*) G, around and *φερυ* (*phero*) to carry; the circumference.

Plane, *planus*, L, level.

Prolate, *pro* L, forth, *latus* the side. A term applied to the spheroid, formed by the rotation of an ellipse about the longer axis.

Protractor, *protractus* L, drawn forth. A mathematical instrument for measuring angles.

Quadrangular, *quadra* L, a square; and *angulus*, an angle: having four angles.

Quadrature, *quadratus* L, squared.

Quadrilateral, *quadra* from *quatuor* L, four, and *latus* a side; a four-sided figure.

Quindecagon, *quinque* L, five, δεκα (*deca*) ten and *γωνια* (*gonia*) G, an angle; a plane figure with fifteen angles.

Quotient, *quoties*, L, how often.

Radius, *radius* L, a sunbeam, a spoke of a wheel. Plural, *radii*.

Ratio, *ratio* L, proportion.

Rectangle, *rectus* L, right; and *angulus*, an angle.

Rectilineal, *rectus* L, right, and *linea*, a line.

Regular bodies. Those which are comprehended by like, equal, and regular plane figures, whose solid angles are all equal. (Maunder's Treasury.)

Regular Curves,—such as are always curved after the same geometrical manner. (Ibid.)

Residual, *residuum* L, the remainder; thus, after taking one figure from another, the remainder is called the residual figure.

Rhombus, *ρομβος* (*rombos*) G, a rhombus, a distorted square.

Rhomboid, *ρομβος* (*rombos*) G, and *ειδος* (*eidos*) resemblance; a figure resembling a rhombus; a distorted oblong.

Scalene, *σκαληνος* (*skalenos*) G, unequal.

Section, *sectus* L, cut.

Sector, from the same. (A part of a circle intercepted between an arc and two radii.) A mathematical instrument containing various scales, and movable on a pivot, so as to fit all radii. The real inventor of this valuable instrument is unknown; yet of so much merit has the invention appeared, that it was claimed by Galileo, and disputed by nations. *For a minute description of it, see* KENTISH'S "TREATISE ON A BOX OF INSTRUMENTS AND THE SLIDE RULE."

Segment, *segmentum* L, a shred, or paring.

Semicircle, *semi* L, half and *circulus* a circle.

Sine, *sinus* L, a bay, a winding.

Solid, *solidus* L, firm.

Spiral, *σπειρα* (*speira*) G, a winding.

Surface, sur for *super* L, upon and *facies* the face.

Superficies from the same.

Supplement, *supplementum* L, an addition.

Tangent, *tangens*, L, touching; a line touching a circle.

Tetragon, *τετρακις* (*tetrakis*) four, and *γωνια* (*gonia*) G, a corner; a square.

Theodolite, *θεκομαι* (*thedomi*) to see; *δολιχος* (*dolichos*) G, far. A mathematical instrument, used in surveying, for taking angles.

Transverse, *trans* L, over, *versus* turned, thrown.
Trapezium, τρικπεζα (*trapeza*) G, a table.
Trapezoid, from the same; and ειδος (*eidos*) G, a resemblance.
Triangle, *tres*, *tria* L, three and *angulus* an angle.
Trigonometry, τρεις, τζια, (*treis tria*) three; γωνια (*gonia*) an angle and μετρον (*metron*) G, a measure. The art of measuring the sides and angles of triangles.
Trisect, *tres*, *tria* L, three; *sectus*, cut.
Undecagon, *unus* L, one δεκα (*deka*) ten and γωνια (*gonia*) G, a corner; a plane figure having eleven angles.
Variable quantities. Such as are either continually increasing or diminishing.
Vertex, *vertex* L, the top.
Zenith, (*Arabic*) The point over head, opposite the Nadir.

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